A Convertible Equation Pair for the Vapor Pressure $P_s = f(T)$ and the Saturation Temperature $T_s = f(p)$ of Ordinary Water Substance

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The paper presents a convertible equation pair for the vapor pressure $p_s = f(T)$ and the saturation temperature $T_s = f(p)$ of ordinary water, and presents a discussion of recently developed numerically consistent equation pairs. The equations have been developed in accordance with the project "New Industrial Formulation" of the International Association for the Properties of Water and Steam (IAPWS). The convertible equation pair was derived from the implicit equation $f(p_s,T_s) = 0$ which is a polynomial of the second degree both in transformed pressure p_s and transformed temperature Ts with eight coefficients altogether. It was developed by using a special approximation algorithm connecting the modified structure optimization algorithm of Wagner and a simultaneous steady approximation method minimizing the maximum error. In spite of the simple structure of the implicit quadratic equation, it is possible to fulfill the very high accuracy given for the vapour pressure by the International Skeleton Tables of Water and Steam (IST-85, Rev. 1994) by using suitable transformations for p_s and T_s. For calculating properties at the saturation curves up to the critical point using an equation of state in connection with this saturation equation pair, it was fitted to the slope at the critical point accurately. In addition, the values at the triple, the critical and the normal boiling points are met exactly. The main advantage of the convertible equation pair is, that it does not have any numerical consistency error. This fact is very important for the application in thermodynamic process modeling. By using the explicit saturation temperature equation, any iteration of the vapor pressure equation is avoided. In addition to these features, the calculation of the new saturation equations needs considerably less computing time than the corresponding calculation using the current standard "The IFC-67 Formulation of Water and Steam for Industrial Use". Due to these characteristics, the convertible equation pair is a part of the equation set proposed for new Industrial Formulation of Water and Steam by IAPWS. Since, the very accurate experimental data of water are met, the concept using an implicit quadratic equation $f(p_s, T_s) = 0$ for calculating $p_s = f(T)$ and $T_s = f(p)$ can also be applied to other fluids.